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N91-19518

A STATUS REPORT ON THE ANALYSIS OF THE NOAA-9 SBUV/2 SWEEP MODE SOLAR IRRADIANCE DATA

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INTRODUCTION

Monitoring of the near ultraviolet (UV) solar irradiance is important because the solar UV radiation is the primary energy source in the upper atmosphere. The solar irradiance at wavelengths shortward of roughly 300 nm heats the stratosphere via photodissociation of ozone in the Hartley bands. Shortward of 242 nm the solar UV flux photodissociates O_2, which is then available for ozone formation. Upper stratospheric ozone variations coincident with UV solar rotational modulation have been previously reported (Gille et al., 1984). Clearly, short and long-term solar irradiance observations are necessary to separate solar-forced ozone variations from anthropogenic changes.

The SBUV/2 instrument onboard the NOAA-9 spacecraft has made daily measurements of the solar spectral irradiance at approximately 0.15 nm intervals in the wavelength region 160-405 nm at 1 nm resolution since March 1985. These data are not needed to determine the terrestrial ozone overburden or altitude profile, and hence are not utilized in the NOAA Operational Ozone Product System (OOPS). Therefore, assisted by ST Systems Corporation, NASA has developed a scientific software system to process the solar sweep mode data from the NOAA-9 instrument. This software will also be used to process the sweep mode solar irradiance data from the NOAA-11 and later SBUV/2 instruments.

The purpose of this status report is to provide an overview of the software system and a brief discussion of analysis findings to date. Several outstanding concerns/problems will also be presented.

SOFTWARE OVERVIEW

The TIROS SBUV/2 sweep mode solar flux generation software system is based on the Nimbus-7 SBUV Continuous Scan and Solar Flux (CSSF) Products Generation Software (Schlesinger et al., 1988). The TIROS software itself was developed independently, with no adaptation of the Nimbus software. The SBUV/2 software system, shown schematically in Figure 1, consists of 1) a Stripping Program, "SUN1B", which extracts all data other than discrete earth view data (which comprises approximately 90% of the SBUV/2 data) from the monthly SBUV/2 1b data tapes and writes these data to monthly "disk 1b" datasets, where one dataset member is written for each day of the month, and 2) a Sweep Mode Program, "SUNSWP", which uses the "disk 1b" datasets and produces calibrated sweep mode solar irradiance disk datasets. We have also developed additional programs to extract, display, and analyze the solar products. In addition to scan-by-scan solar irradiance values, the Sweep Mode Program writes three separate temporal averages: orbital average, daily average, and Bartel's period (27-day solar rotation period) average; and 5 nm spectral averages (computed using the daily averaged data, with the ± 2.5 nm spectral averages reported every 2.5 nm) onto the disk datasets. Two of these datasets are written per calendar year, with one Bartel's period per dataset member. The orbital average is computed and reported only on those days for which solar measurements are made on more than one orbit. Under normal operation, where one solar measurement is made per day, the orbital average equals the daily average, and only the daily average is reported.

Results from the SBUV/2 instrument characterization effort are used as external input to the software (in fact there is much synergism because the sweep mode solar data constitutes a substantial portion of the data used to characterize the SBUV/2 instrument's in-orbit change). Evolution of the instrument characterization has already and will continue to led to refinements in the Sweep Mode Program and reprocessing of the solar irradiance data. The software is therefore constructed of modules structured so as to minimize the impact of changes in the instrument characterization and facilitate future upgrades. SUN1B is constructed of 8 modules with a total of approximately 600 lines of source code, excluding comment lines. SUNSWP contains 39 modules with a total of over 3300 lines of source code, excluding comment lines. All software is developed in FORTRAN 77 and operates on the NASA/GSFC IBM 3081 under MVS.

STATUS

The Stripping and Sweep Mode Programs are fully developed, tested, and functional. Refinements to the latter software continue as more is learned about the NOAA-9 instrument. To date all solar flux (here and henceforth we use solar flux or solar irradiance to mean sweep mode solar irradiance) data from the commencement of the measurement on 12 March 1985 through 10 July 1988 have been processed.

Over the past five years much has been learned regarding the behavior of the NOAA-9 SBUV/2 instrument. Several important instrument characteristics, specifically the linearity correction, the wavelength dependence of the photomultiplier tube (PMT) gain, and the time dependence of the PMT gain, have been incorporated into the software. However, much remains to be learned. Corrections for time dependent changes in the instrument optics throughput and/or diffuser absolute reflectance and goniometric characteristic are not yet included. Additionally, the goniometric correction is based on the nominal, predictive orbit/attitude information available on the 1b tapes; no corrections for spacecraft departures from the predictive ephemeris, spacecraft departures from nominal attitude, or the small SBUV/2-to-spacecraft mounting angle misalignment are made. Finally, we have recently learned that there are periods during which the solar location data are based on the yaw axis gyrocompass output rather than on the spacecraft solar sensor (F. G. Cunningham, private communication). If a bias exists between the two types of solar location determinations, then there will be an impact on the derived NOAA-9 irradiances. We are presently investigating this potential problem.

MAJOR FINDINGS

The NOAA-9 SBUV/2 "day 1" solar irradiance is presented in Figure 2 as is the Nimbus-7 SBUV "day 1" solar spectra. In this rather insensitive semi-log presentation, agreement between the two instruments is quite good. However, upon closer inspection, significant differences are observed. The ratio of the NOAA-9 SBUV/2 to Nimbus-7 SBUV "day 1" irradiances is shown in Figure 3. The Nimbus data have been corrected for solar change occurring over the intervening period (roughly 6.5 years) using an empirical estimate based on the Mg II core-to-wing index (Heath and Schlesinger, 1986). The correction for solar variability is roughly 7% at 200 nm. The adopted solar variability correction is approximately 3% at 250 nm and decreases to less than 1% longward of 275 nm. The solar variability correction used here compares favorably with independent measurements of long-term solar change (Lean, 1987).

Four significant aspects of the comparison between the NOAA-9 SBUV/2 and Nimbus-7 SBUV "day 1" spectra are noted. These features are present in all comparisons made to date, including comparisons of data taken on the same day, and therefore indicate absolute calibration biases between the two instruments. First, the NOAA-9 solar flux is approximately 10% larger than the Nimbus-7 flux. Second, this bias is wavelength dependent, decreasing from 14% at 200 nm to 6% at 350 nm, then increasing again to about 13% at 400 nm. The significant wavelength-dependent bias between two instruments, particularly in the wavelength region used for ozone determination (250-340 nm) and longward, is rather surprising. Longward of approximately 250 nm quartz halogen lamps are used as the primary light source during the radiometric calibration. The National Institute for Standards and Technology, which provides the calibration of these lamps, estimates that the three sigma uncertainty of the lamp calibrations ranges from 2.2% at 250 nm to 1.4% at 350 nm (Walker, et al., 1987). Even with additional uncertainties entering into the measurement from other sources of error in the prelaunch radiometric calibrations, a 10% relative accuracy with a 10% wavelength dependence is outside the expected error range.

A third aspect of Figure 3 is the spectral feature centered on 232 nm. Both deuterium and argon arc lamps were used to calibrate SBUV/2 shortward of approximately 250 nm. Near 230 nm the instrument's radiometric response changes by approximately 15% over a rather narrow spectral region. Comparisons of the deuterium lamp-based and argon lamp-based radiometric sensitivity curves show a feature similar to the SBUV/2 to SBUV bias in this region. Hence, this feature is probably due to a small error in the NOAA-9 radiometric calibration. Preliminary intercomparisons of the solar data from the first Shuttle SBUV (SSBUV) mission (STS-34) with the NOAA-9 SBUV/2 and the Nimbus-7 SBUV data support the hypothesis that the spectral feature seen in Figure 3 at 232 nm arises from an error in the SBUV/2 calibration. Further work needs to be done in this area, however it is probable that the NOAA-9 SBUV/2 sweep mode irradiance radiometric calibration will need to be revised, at least in the region shortward of approximately 240 nm. This problem has no impact on the NOAA-9 ozone data.

A final aspect of Figure 3 is the increase in the noise level of the comparison in the region 270 to 290 nm. In this region, the SBUV/2 data are output in the lower portion of gain Range 3 and count rates as low as 59 counts (after removal of the electronic offset) are experienced. The standard deviation of the Range 3 electronic offset is approximately 4 counts, thus these data have a one sigma noise of approximately 7% due to the sample-to-sample variation in the offset. Unfortunately, this spectral region contains the Mg II doublet, which is very useful for monitoring short and long-term solar variability. As will be seen, the large noise in the SBUV/2 solar data in this region masks the short-term variability. It is for this reason that the instrument makes daily discrete mode measurements about the 280 nm Mg II doublet.

Figures 4 and 5 present a preliminary intercomparison of the NOAA-9 SBUV/2 solar irradiances with data from Dr. James Mentall's rocket-borne instrument. The relatively large noise level of the comparison shown in Figure 5 arises in part from uncertainty entering into the comparison during the interpolation from the wavelength scale of the rocket instrument to the wavelength scale of SBUV/2. This uncertainty is especially apparent at the Ca II h and k solar absorption lines at 396.8 and 393.3 nm. The two solar measurements agree to within approximately 10%, however there exists a 20% wavelength dependence in the 300 to 370 nm region. The shape of the SBUV/2-to-rocket bias is distinct from the shape of SBUV/2-to-SBUV bias, suggesting that wavelength dependent calibration errors exist in at least two of the three instruments. While the SBUV/2-to-rocket comparison shown in Figure 5 is too noisy to be used to accurately assess possible calibration errors over a narrow wavelength region, we note a slight change in the noise level of the comparison near 230 nm. The SBUV/2 irradiances are higher than both the SBUV and rocket irradiances.

As might be expected from the experience of previous BUV-type instruments, the radiometric sensitivity of the NOAA-9 SBUV/2 instrument has not remained constant. Figure 6 presents the ratio of NOAA-9 SBUV/2 solar irradiance outputs taken one, two, and three years after the start of the solar measurement (roughly 14 March 1986, 1987, and 1988, respectively) to the initial solar irradiance measurement. These data have not been corrected for solar irradiance changes, however March 1985 through March 1987 was a period of low solar activity. During late 1987 solar activity began to increase, and by mid-1988 the Mg II solar activity index had increased by roughly 3.5% relative to the index in 1986 (Donnelly, 1988). Using the NOAA-9 Mg II index and the Nimbus-7 scaling factors, we estimate true solar change over the first three years of the SBUV/2 operation to range from approximately 3-4% at 200 nm, to 1% or less at and longward of 265 nm. Thus, in the first approximation, the changes shown in Figure 6 can be attributed to instrument radiometric sensitivity drift. The instrument solar output is seen to have decreased by between approximately 1% at 400 nm to 5% at 200 nm over the first year of data. The output decrease during second year of operation roughly equaled that observed during the first year of operation, and at the end of two years, the output decreased by approximately 2% at 400 nm to nearly 10% at 200 nm relative to the initial output. As seen in Figure 6 and the time series plots that follow, the instrument sensitivity decrease apparently flattened out during the third year of operation. However, shortward of 250 nm some of this apparent decline in the instrument sensitivity degradation rate is due to an increase in the solar irradiance offsetting the instrument throughput decrease. Based on the Mg II index, shortward of about 250 nm the solar irradiance in mid-1988 was anywhere from approximately 1% to 4% higher than the irradiance in early 1987. After correction for an estimated 3-4% solar flux increase at 200 nm, we estimate roughly a 4-5% instrument sensitivity decrease at 200 nm during the third year of operation. It is interesting to note that longward of 240 nm the spectral shape of the sensitivity change is similar to the shape of the SBUV/2-to-SBUV bias. We plan to investigate whether or not this is coincidental.

The time series of the SBUV/2 391.3 nm output is presented in Figure 7. The most striking aspect of this figure is the approximate 1.3% day-to-day fluctuation in the irradiance output. This same fluctuation is also clearly seen in the 202.2 nm time series presented in Figure 8. Laboratory tests on later flight units indicate that this fluctuation is likely due to a 0.25° day-to-day variation in the NOAA-9 SBUV/2 solar diffuser deployment angle. At the approximate 70° angle of incidence of the solar ray with respect to the diffuser normal at which the SBUV/2 instruments obtain solar measurements, a 0.25° variation in the diffuser deployment angle translates into roughly a 1.2% error in the derived irradiance. The solar diffuser mechanisms on the NOAA-11 and later SBUV/2 instruments have been modified to correct this problem. Preliminary analysis confirms that the NOAA-11 SBUV/2 solar data is free of this error (H. Weiss, private communication).

The error caused by the day-to-day fluctuation in the diffuser deployment angle is wavelength independent in first order, hence ratios of solar irradiance time series such as that shown in Figure 9 are nearly free of this error. However, because the error in the derived irradiance is given by $\cos(\Theta + \Delta\Theta)/\cos(\Theta)$ where Θ is about 70°, and because this angle increases with time as the spacecraft continues in its orbit, the error increases at the shorter wavelengths (in the sweep scan mode the SBUV/2 instruments scan from long to short wavelengths). Hence there exists a small wavelength dependence to the error. Since the exact time the solar measurement commences varies from day-to-day, there is also a variability in the exact magnitude of the induced error at given wavelength; this effect can be seen in both Figures 7 and 8. Proper correction for errors induced by the day-to-day fluctuation in the diffuser deployment angle is therefore not straightforward. We are continuing to evaluate this problem at present. Since a given scan of the discrete mode wavelengths is completed in 24 seconds, the discrete mode solar irradiance data are less susceptible to these second order effects, and the day-to-day fluctuation in the discrete mode irradiance should approximately cancel out when wavelength pairs are used for total ozone determination. The effect on the profile wavelengths needs further investigation.

A second aspect noted in Figure 7 is the much larger day-to-day variation in the instrument solar output prior to October 1985. This variation seems to occur only at wavelengths longward of approximately 300 nm. We are still investigating the cause of this fluctuation. A similar fluctuation is observed at all wavelengths in discrete mode solar data during the first few months in orbit.

During July and August of 1986 the solar irradiance measurement was made once per orbit (there are 13 or 14 orbits per day) rather than once per day as is done operationally. This period is visible in both Figures 7 and 8 as a period of reduced day-to-day fluctuation. The diffuser plate was stowed after each orbit's solar measurement in order to obtain the operational ozone data and to protect the diffuser plate from contaminants. The reduced noise results from the square root of N reduction achieved as the number of deployments was increased from 1/day to 14/day. Note too that the average daily irradiance during this period is biased with respect to the surrounding data. This is due to the fact that with multiple deployments within a single day, the diffuser will on some fraction of orbits deploy to the normal angle and on some orbits will deploy to the alternate angle.

Over the declining portion of solar cycle 21 the solar irradiance near 400 nm has been estimated to vary by on the order of 0.2% or less (Schlesinger et al., 1988), and during the solar minimum period 1985-1988 the 391.3 nm irradiance measured should be essentially constant. Assuming the solar output to have remained constant at 391.3 nm, we estimate that the NOAA-9 SBUV/2 sensitivity degraded by 1.4% at this wavelength over the first three years of operation.

Figure 9 presents the ratio of the time series at 202.2 nm to that at 391.3 nm. The near removal of the 1.3% day-to-day fluctuation in the instrument output is immediately apparent. Note however the day-to-day fluctuation in the time series ratio during the early part of the data record. Again, this error is manifest only in the longer wavelength data and is introduced into the ratio by the 391.3 nm data. With the removal of the day-to-day fluctuation (except for the mid 1985 problem), 27-day solar rotational modulation is easily observed at 202.2 nm. In 1988 the strength of the rotational modulation increased and the modulation changes from a predominant 27-day periodicity to a predominant 13-day periodicity. Figures 10 and 11, respectively, present the Nimbus-7 SBUV and NOAA-9 SBUV/2 discrete mode Mg II core-to-wing indices. Note the excellent qualitative agreement amongst these three distinct measurements. Due to slightly different wavelengths and, when comparing SBUV with SBUV/2, slightly different bandpasses, the three Mg II indices (SBUV, SBUV/2 discrete mode, and SBUV/2 sweep mode) are not identical. We plan to perform quantitative comparisons of the strengths of the solar rotational variability as determined from the NOAA-9 SBUV/2 and Nimbus-7 SBUV instruments during the next few months. This comparison has yet to be done, therefore the estimates of solar activity used in this paper are rather rough because we are using the Mg II index from one instrument and the scaling factors from another instrument.

Also seen in Figure 9 is an approximate 8% decrease in the relative 202.2 nm to 391.3 nm output during the period from March 1985 through December 1987, then roughly a 2% increase between December 1987 and July 1988. Note too the change in slope corresponding to the every orbit solar measurement period in the summer of 1986. Long-term solar changes must be considered when using the 202.2 nm data to assess instrument sensitivity change. However, as seen in Figures 10 and 11, from March 1985 through February 1987 solar activity was low. Except for a 1-1.5% rotational modulation, we estimate that the 202.2 nm irradiance was constant to within 1% during this period. Therefore, the 8% decrease in relative instrument output during this period provides a good first order measurement of true instrument sensitivity change. Adding this change to an estimated 1% decrease in the 391.3 nm sensitivity, we estimate that the NOAA-9 SBUV/2 202.2 nm sensitivity decreased by between 8.5 and 9.5% from March 1985 through February 1987.

As shown in Figure 11, the Mg II core-to-wing index increased by approximately 4% from January 1987 through June 1988. The SBUV-based scaling index is nearly unity at 202.2 nm (Heath and Schlesinger, 1986). Thus, in the absence of a wavelength dependent instrument sensitivity change, we would expect to observe roughly a 4% increase in the ratio of the 202.2 nm to 391.3 nm SBUV/2 irradiances. A somewhat smaller increase, about 2%, is actually observed during the latter half of 1987 and the first half of 1988 because of ongoing wavelength dependent degradation. Using the slope of the 202.2nm/391.3nm output ratio determined from September 1986 through February 1987, and assuming this rate to have remained constant through July 1988, we estimate the relative uncorrected instrument drift for the period January 1987 through June 1988 to be about 2%. This simplified analysis suggests good consistency between the empirical model of the rotational and long-term solar change developed for SBUV on Nimbus-7 and the NOAA-9 SBUV/2 data, at least at 202.2 nm. Clearly, we have just begun the analysis in this area.

Figures 12 and 13 present the time series of the sweep mode solar irradiance data obtained near the discrete mode wavelengths 252 and 340 nm, respectively. The irradiances shown here are the average of the 13 individual irradiance values spanning the SBUV/2 slit width. In addition, we have manually reduced the irradiances obtained on days when the diffuser deployment angle was shifted by 0.25° with respect to the nominal deployment angle downward by 1.3%. The most significant aspect of these two figures is the rapid decrease in the instrument solar output coincident with the frequent solar measurement period in mid-1986. These figures present the first clear evidence that the NOAA-9 SBUV/2 instrument, similar to the Nimbus-7 SBUV instrument, degrades as a result of solar exposure. As seen in Figure 9, the effects of the frequent solar measurement are less visible when the ratio of time series at two wavelengths is constructed. This suggests that the SBUV/2 solar degradation rate may not be strongly wavelength dependent. Figures 12 and 13 indicate that the sweep mode solar irradiance data can be very useful for assessing long-term instrument sensitivity change. This is particularly important for the NOAA-9 instrument because of the failure of the onboard calibration system shortly after launch (Frederick et al., 1986).

As previously discussed, due to the noise in the Range 3 low count data, the NOAA-9 SBUV/2 now makes daily discrete mode measurements about the 280 nm Mg II solar absorption line. Shown in Figure 14 is the NOAA-9 Mg II core-to-wing ratio determined from the sweep mode data (the wavelengths 279.79, 279.94, and 280.09 nm were used for the core and the wavelengths 276.54, 276.69, 283.19, and 283.34 nm were used for the wing). Compare this figure to the index determined using the discrete mode data, Figure 11. Except during the frequent measurement period in the summer of 1986, the high noise level of the sweep mode Mg II index masks out the 27-day rotational modulation. However, the long-term behavior of the sweep mode index, in particular the 4% increase observed between 1985 and mid-1988, agrees favorably with the discrete mode index. Therefore, the sweep mode index can be used to assess long-term, if not short term, variability. We are beginning to work with the sweep mode index to see if filtering and/or smoothing may be used to reduce the noise level and assess short term variability.

The preflight goniometric calibration of the NOAA-9 SBUV/2 covered the range of spacecraft centered solar elevation (0° to 20°) and spacecraft centered solar azimuth (30° to 65°) angles expected in orbit. However, as shown in Figure 15, the large drift in spacecraft local time from launch through the present (an ascending node of roughly 1:30 PM to roughly 5:30 PM local time) has resulted in a significant decrease in the spacecraft centered solar azimuth angle. This angle is now less than 30°, and the prelaunch goniometric calibration data no longer spans the needed region. Quarterly tests of the goniometric calibration via position mode solar data have been advocated by STX personnel since the launch of the NOAA-9 spacecraft. Similar tests are now commencing, and analysis of the resulting data as well as the existing sweep mode solar data will be used to derive an extended goniometric calibration.

Commencing with the 16 September 1987 data we began to notice that on some days the sweep mode data acquired at the beginning of the solar measurement was orders of magnitude too low. It appears that once the spacecraft centered solar azimuth angle falls below approximately 40° that data acquired at negative spacecraft centered solar elevation angles is partially or totally occulted. We have developed a simplified algorithm which uses the Cloud Cover Radiometer (CCR) data to identify and exclude the affected monochromator data. The algorithm successfully removed affected sweep mode data during the 1987-1988 shadowing period, which ended in March 1988 when the solar azimuth angle increased to greater than 40°. Although the solar data for late 1988 and 1989 have not been processed yet, examination of the raw data from 1b tape dumps shows a much earlier start for the shadowing effect (approximately August 9), precisely when the azimuth angle again fell below 40° (Figure 15). This effect can be distinguished from the solar array shadowing problem which affected the SBUV/2 solar data during late 1988. A preliminary look at the October 1989 raw data, when the solar azimuth angle was less than 15°, shows additional problems which may invalidate the present correction algorithm. We will continue to investigate these problems.

ONGOING WORK

This status report is intended to provide an overview of the work that has been done to date to process and analyze the NOAA-9 SBUV/2 sweep mode solar irradiance data. This is a work in progress, and much remains to be done. Major lines of current investigation include:

Assessment of the ongoing 1.3% day-to-day fluctuation, with the hope of developing a reasonably straightforward correction. This correction may or may not be wavelength dependent.

Assessment of the day-to-day fluctuation observed only at the longer wavelengths during the first few months of solar observation. At present we do not have a good hypothesis as to the source of this problem.

Assess the impact, if any, of the periodic switch from solar location angles determined using the spacecraft solar sensor to angles determined using the yaw axis gyrocompass.

Quantitative evaluation of the scaling factors between the discrete mode Mg II core-to-wing ratio and rotational modulation at selected sweep mode wavelengths.

Intercomparison of the NOAA-9 and Nimbus-7 scaling factors.

Investigation of the sweep mode Mg II core-to-wing index, including attempts to filter and/or smooth the index to facilitate using the index to evaluate short-term rotational modulation. Quantitative intercomparisons of the SBUV/2 sweep mode Mg II index with the SBUV/2 discrete mode and SBUV indices.

Evaluation of long-term instrument sensitivity change including analysis of the effects of the every orbit solar measurement.

Extension of the goniometric calibration to a wider range of spacecraft centered solar azimuth angles.

Further assessment of the "shadowing" effects.

ACKNOWLEDGEMENTS

We would like to thank Dr. R. F. Donnelly of NOAA/ERL/ARL for supplying the NOAA-9 SBUV/2 Mg II data, Dr. D. F. Heath of ST Systems Corporation for supplying the Nimbus-7 SBUV Mg II data and scaling factors, and Dr. J. E. Mentall of NASA/GSFC for supplying the rocket irradiances. This research was done under contract at the NASA Goddard Space Flight Center, Greenbelt, Maryland.

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SBUV/2 SWEEP MODE SOLAR FLUX
PRODUCTION FLOW CHART

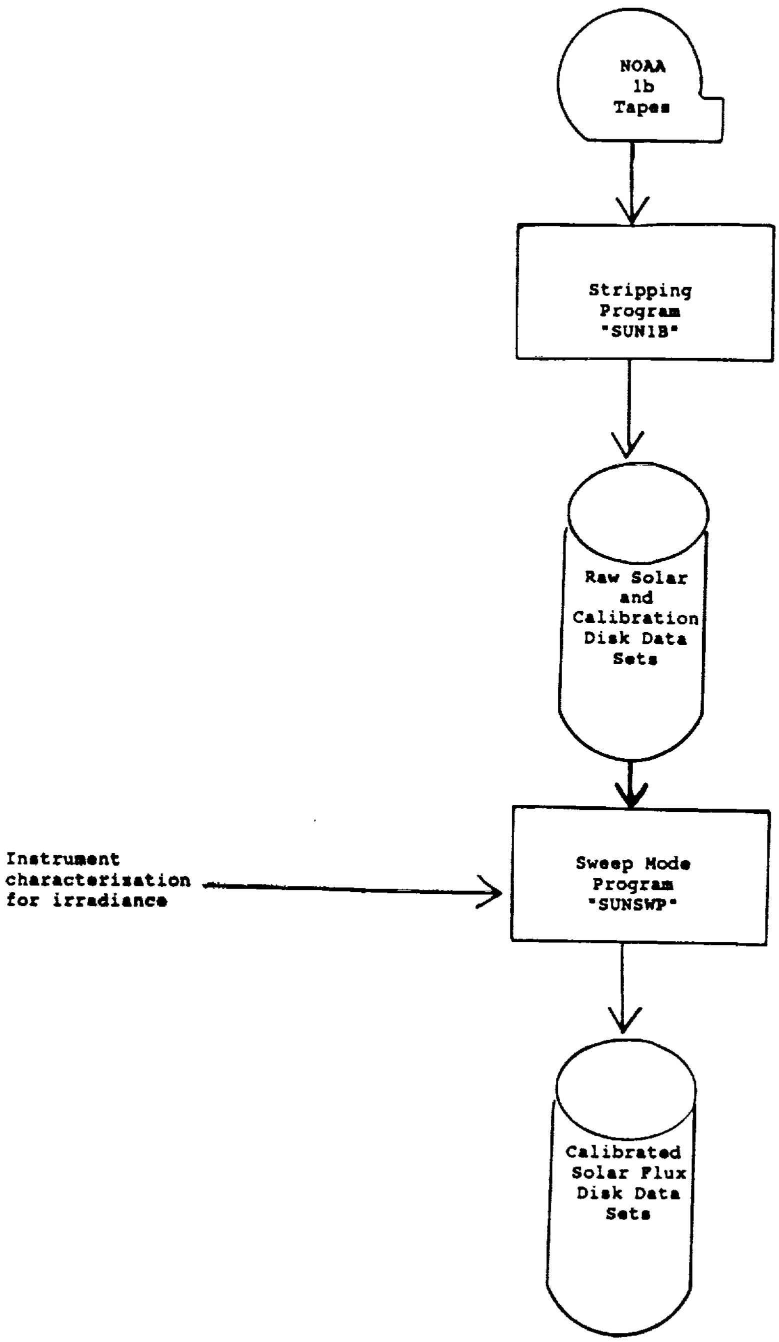


FIGURE 1

FIGURE 2

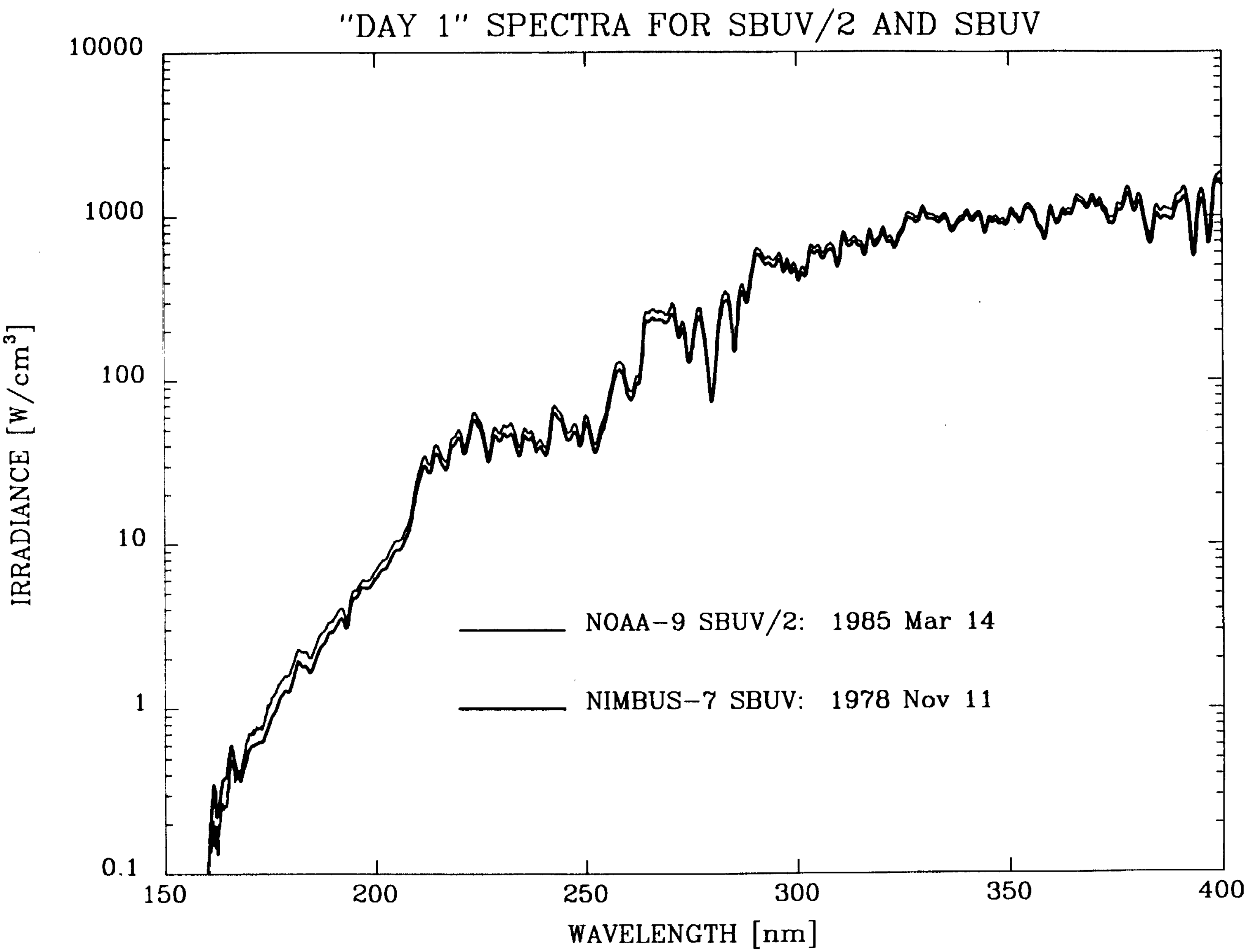
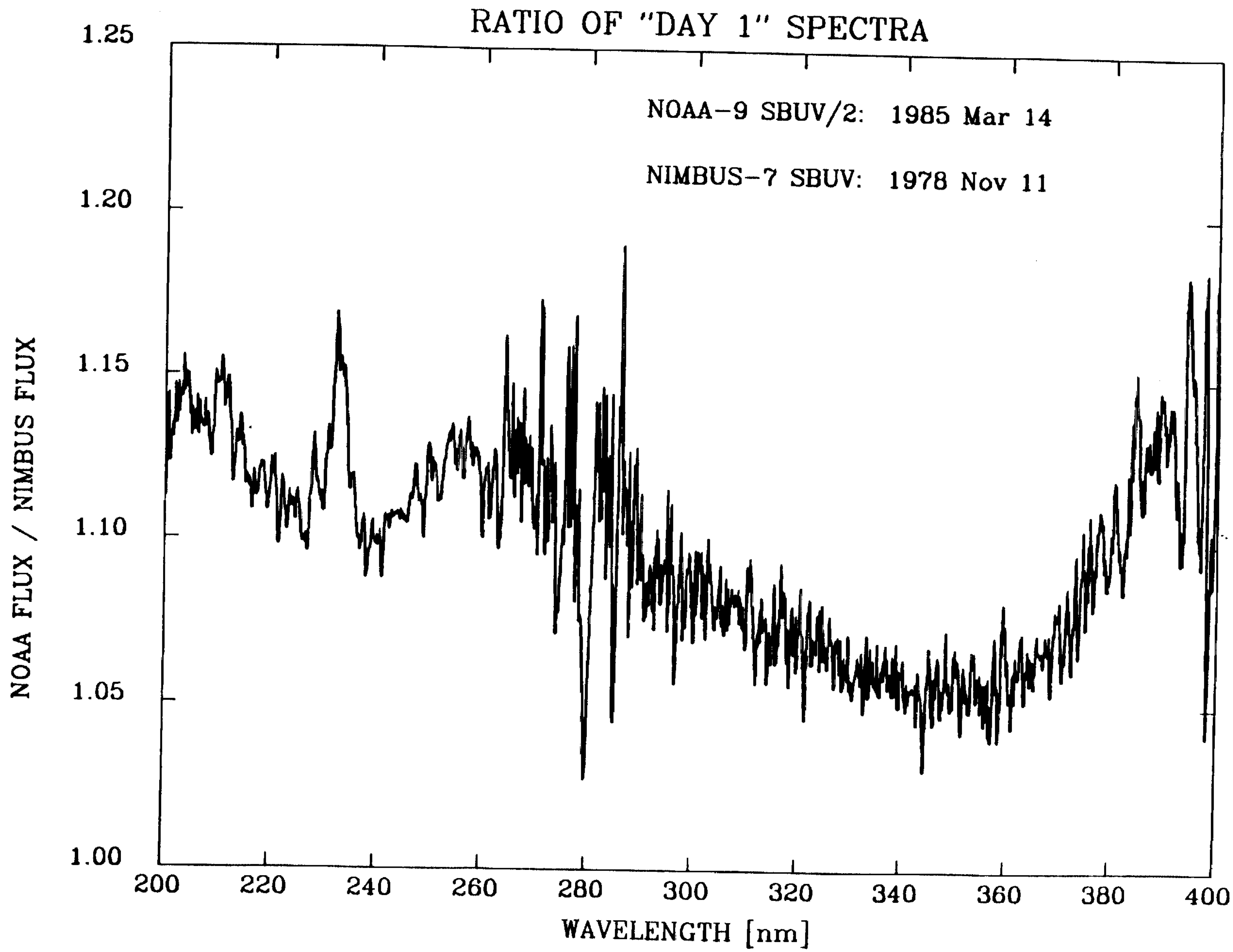

"DAY 1" SPECTRA FOR SBUV/2 AND SBUV
10000
1000
100
10
1
0.1
IRRADIANCE [W/cm3]
150
200
250
300
350
400
WAVELENGTH [nm]
NOAA-9 SBUV/2: 1985 Mar 14
NIMBUS-7 SBUV: 1978 Nov 11

FIGURE 3



RATIO OF "DAY 1" SPECTRA
NOAA-9 SBUV/2: 1985 Mar 14
NIMBUS-7 SBUV: 1978 Nov 11
NOAA FLUX / NIMBUS FLUX
1.25
1.20
1.15
1.10
1.05
1.00
200
220
240
260
280
300
320
340
360
380
400
WAVELENGTH [nm]

FIGURE 4

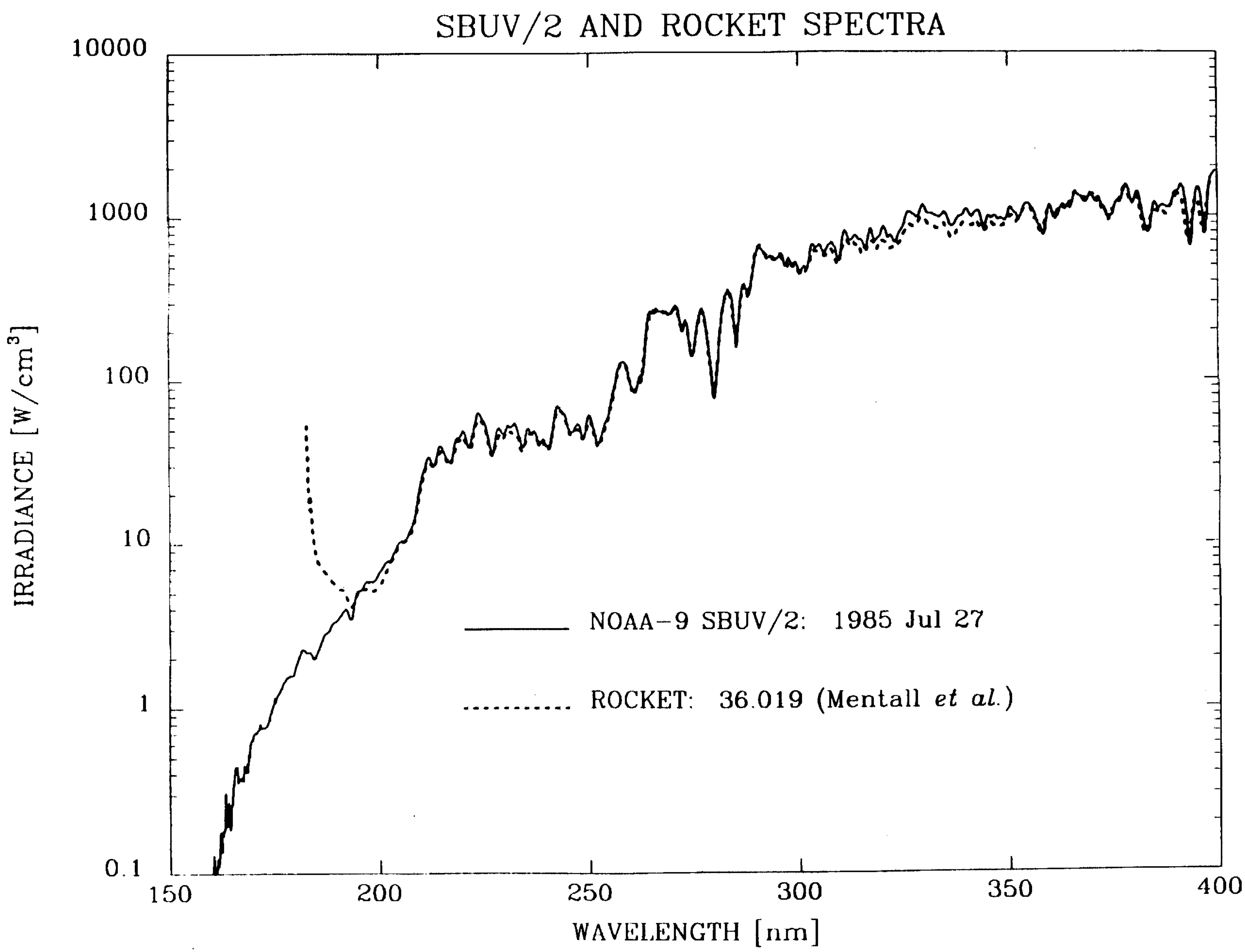

SBUV/2 AND ROCKET SPECTRA
IRRADIANCE [W/cm³]
10000
1000
100
10
1
0.1
150
200
250
300
350
400
WAVELENGTH [nm]
NOAA-9 SBUV/2: 1985 Jul 27
ROCKET: 36.019 (Mentall et al.)

FIGURE 5

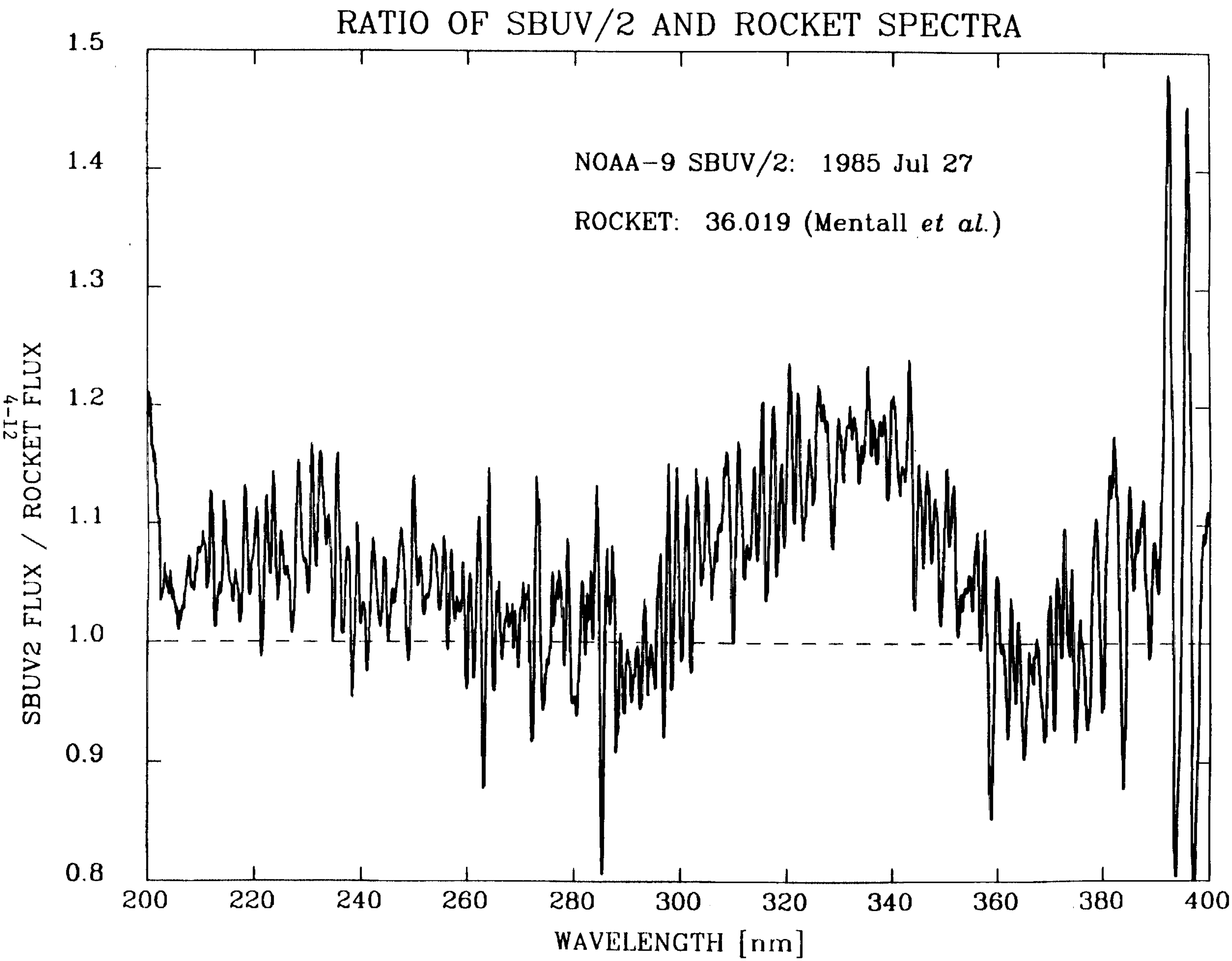
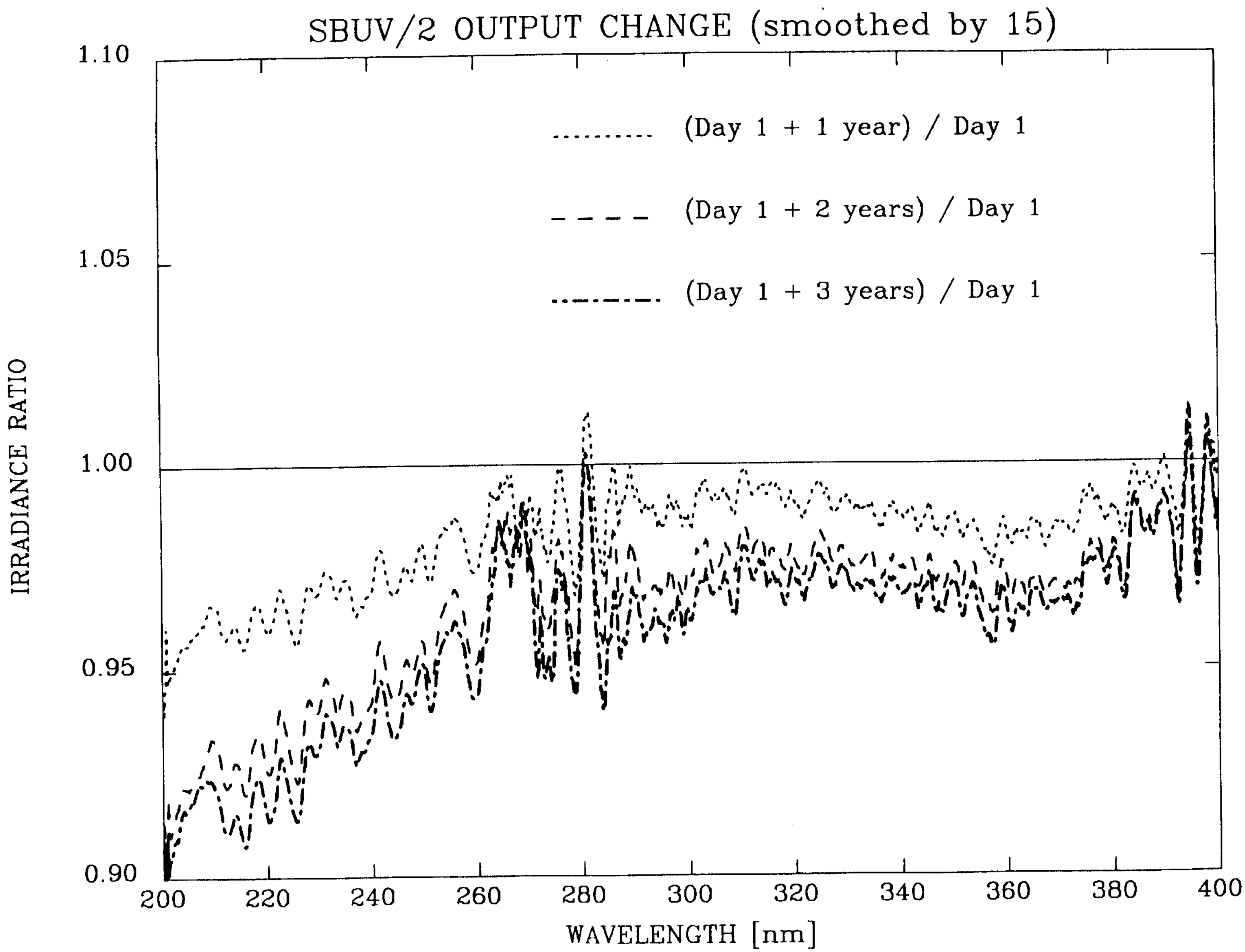
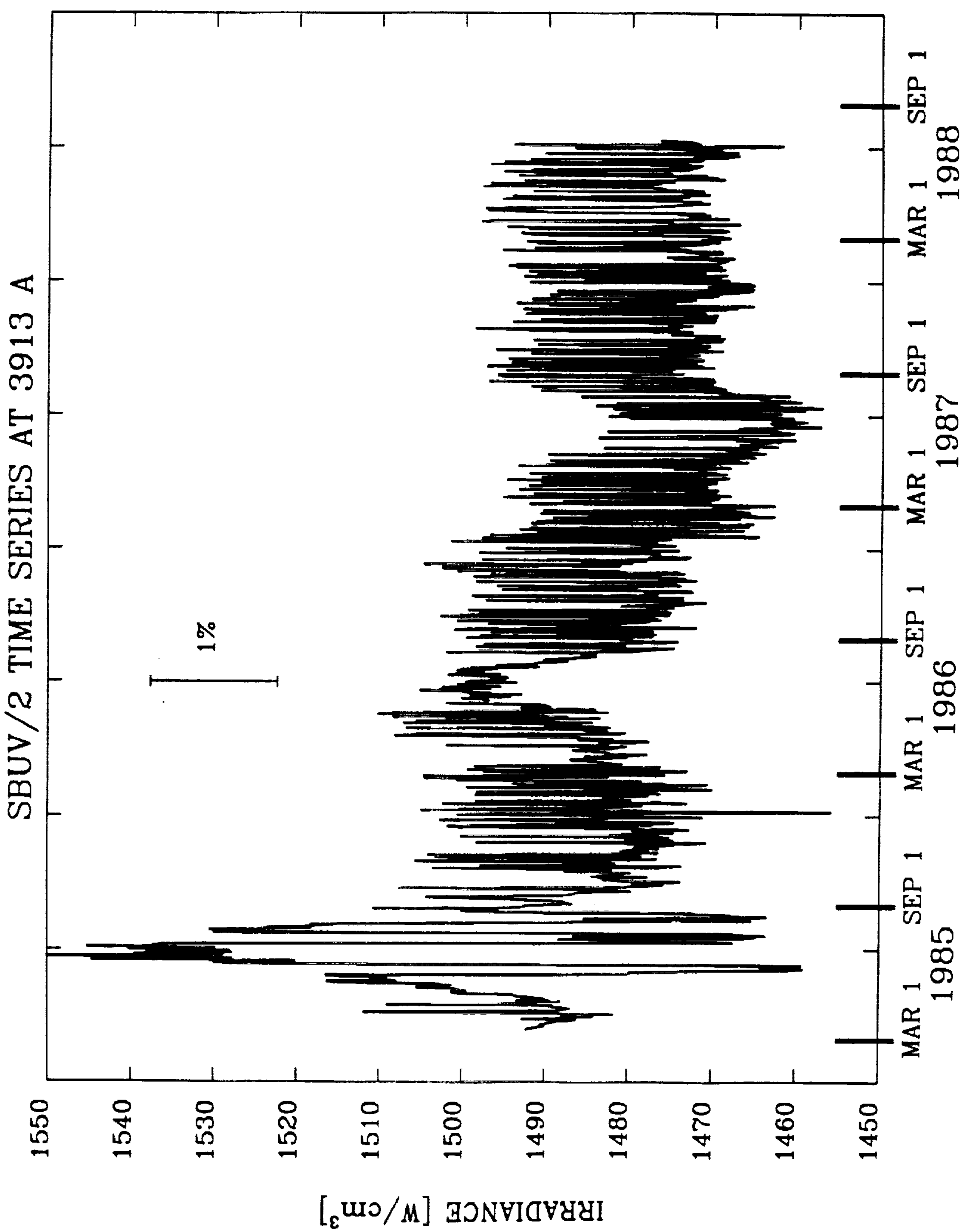

RATIO OF SBUV/2 AND ROCKET SPECTRA
NOAA-9 SBUV/2: 1985 Jul 27
ROCKET: 36.019 (Mentall *et al.*)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
SBUV2 FLUX / ROCKET FLUX
200
220
240
260
280
300
320
340
360
380
400
WAVELENGTH [nm]

FIGURE 6



SBUV/2 OUTPUT CHANGE (smoothed by 15)
(Day 1 + 1 year) / Day 1
(Day 1 + 2 years) / Day 1
(Day 1 + 3 years) / Day 1
IRRADIANCE RATIO
1.10
1.05
1.00
0.95
0.90
200
220
240
260
280
300
320
340
360
380
400
WAVELENGTH [nm]

FIGURE 7



SBUV/2 TIME SERIES AT 3913 A
1%
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
1985
1986
1987
1988
1550
1540
1530
1520
1510
1500
1490
1480
1470
1460
1450
IRRADIANCE [W/cm3]

FIGURE 8

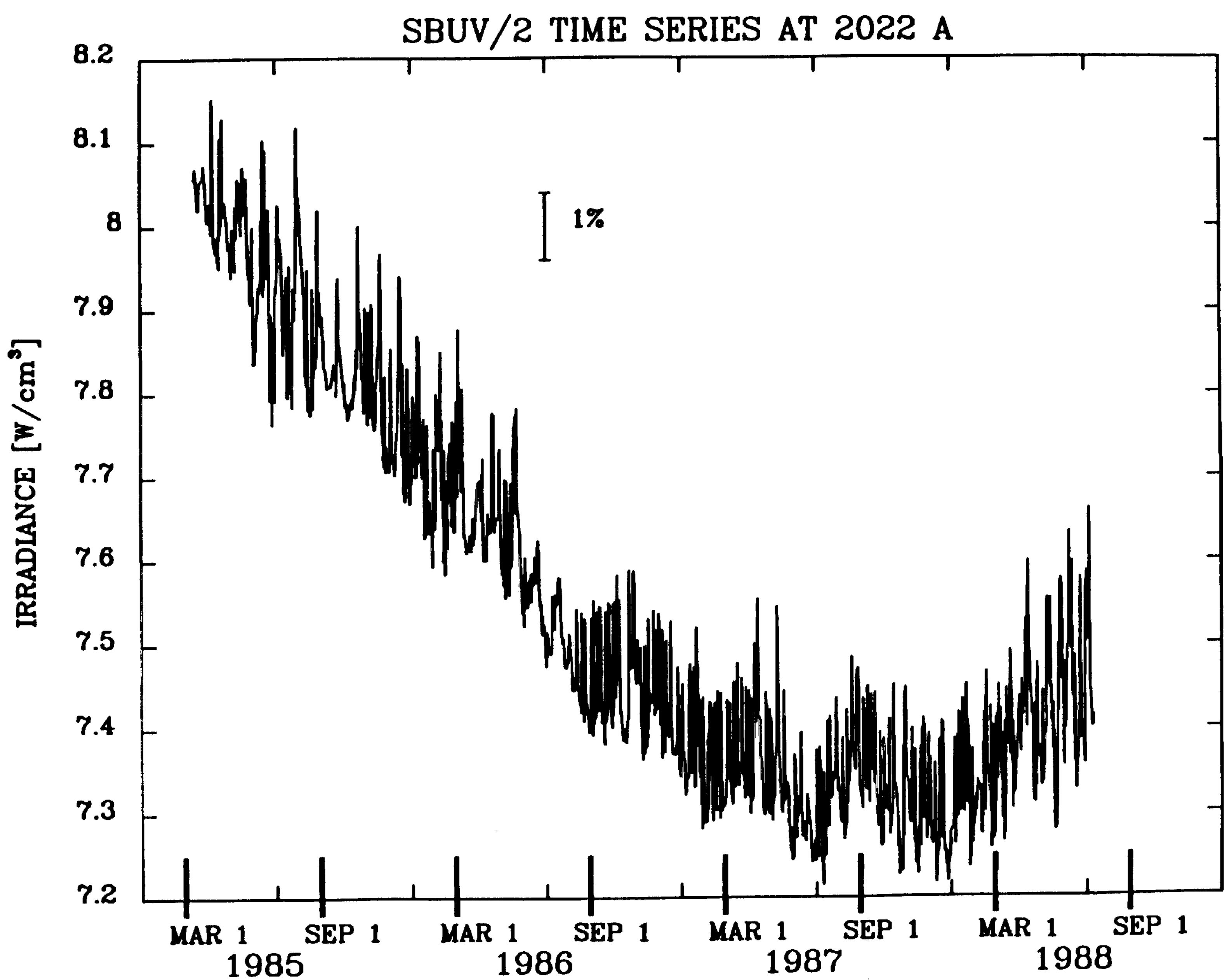
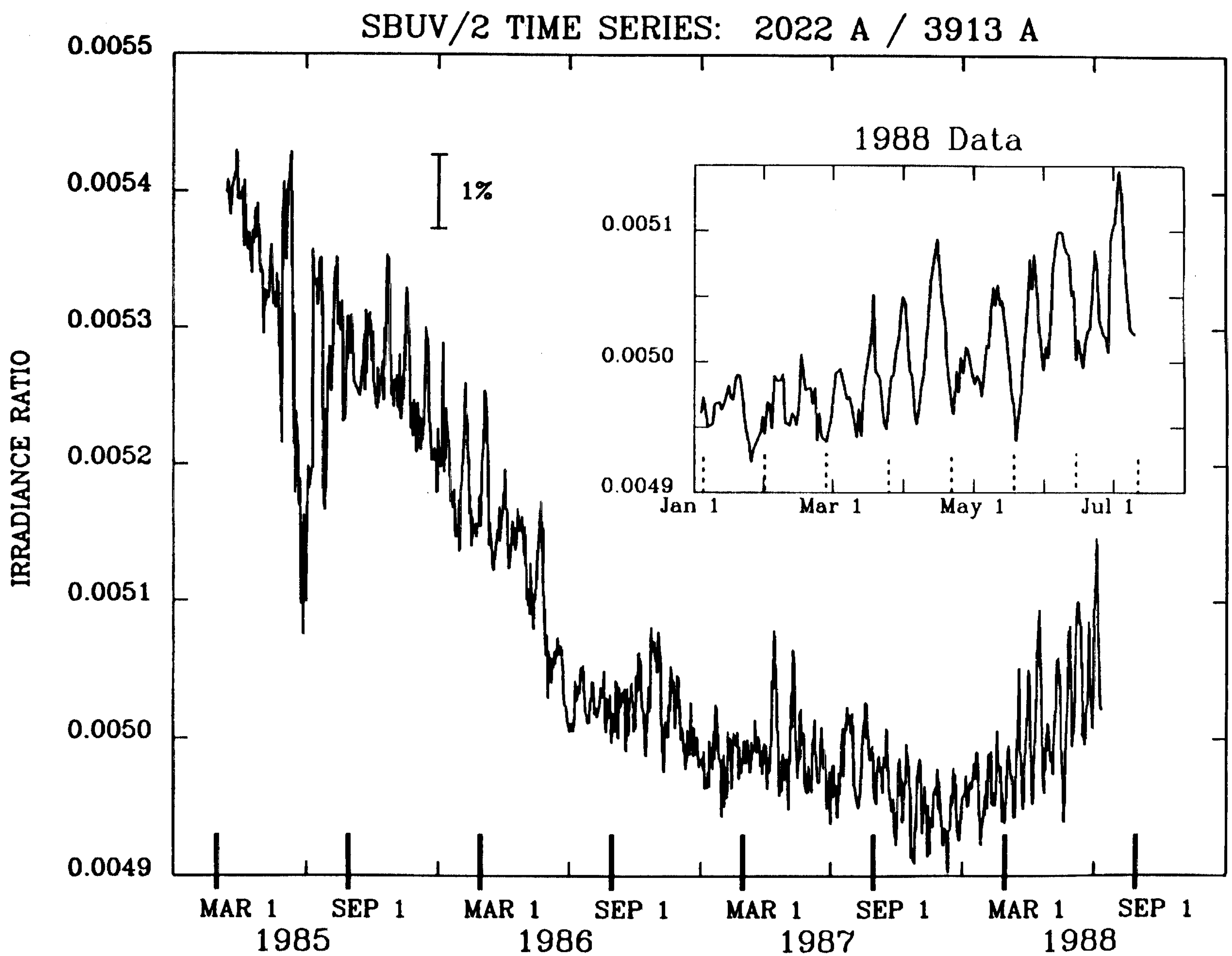
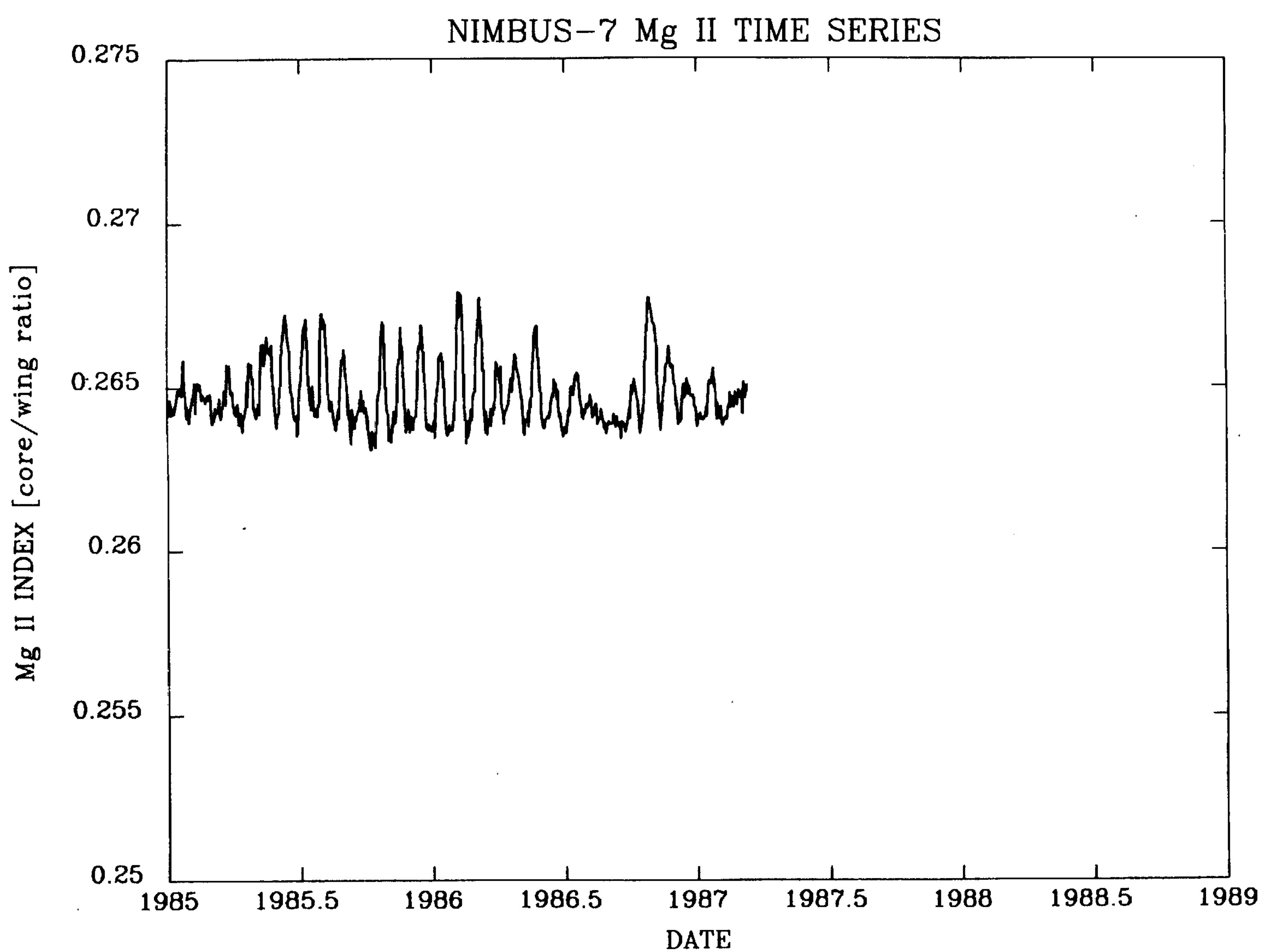

SBUV/2 TIME SERIES AT 2022 A
IRRADIANCE [W/cm³]
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
1%
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
1985
1986
1987
1988

FIGURE 9



SBUV/2 TIME SERIES: 2022 A / 3913 A
IRRADIANCE RATIO
0.0055
0.0054
0.0053
0.0052
0.0051
0.0050
0.0049
1%
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
1985
1986
1987
1988
1988 Data
0.0051
0.0050
0.0049
Jan 1
Mar 1
May 1
Jul 1

FIGURE 10



NIMBUS-7 Mg II TIME SERIES
0.275
0.27
0.265
0.26
0.255
0.25
Mg II INDEX [core/wing ratio]
1985
1985.5
1986
1986.5
1987
1987.5
1988
1988.5
1989
DATE

FIGURE 11

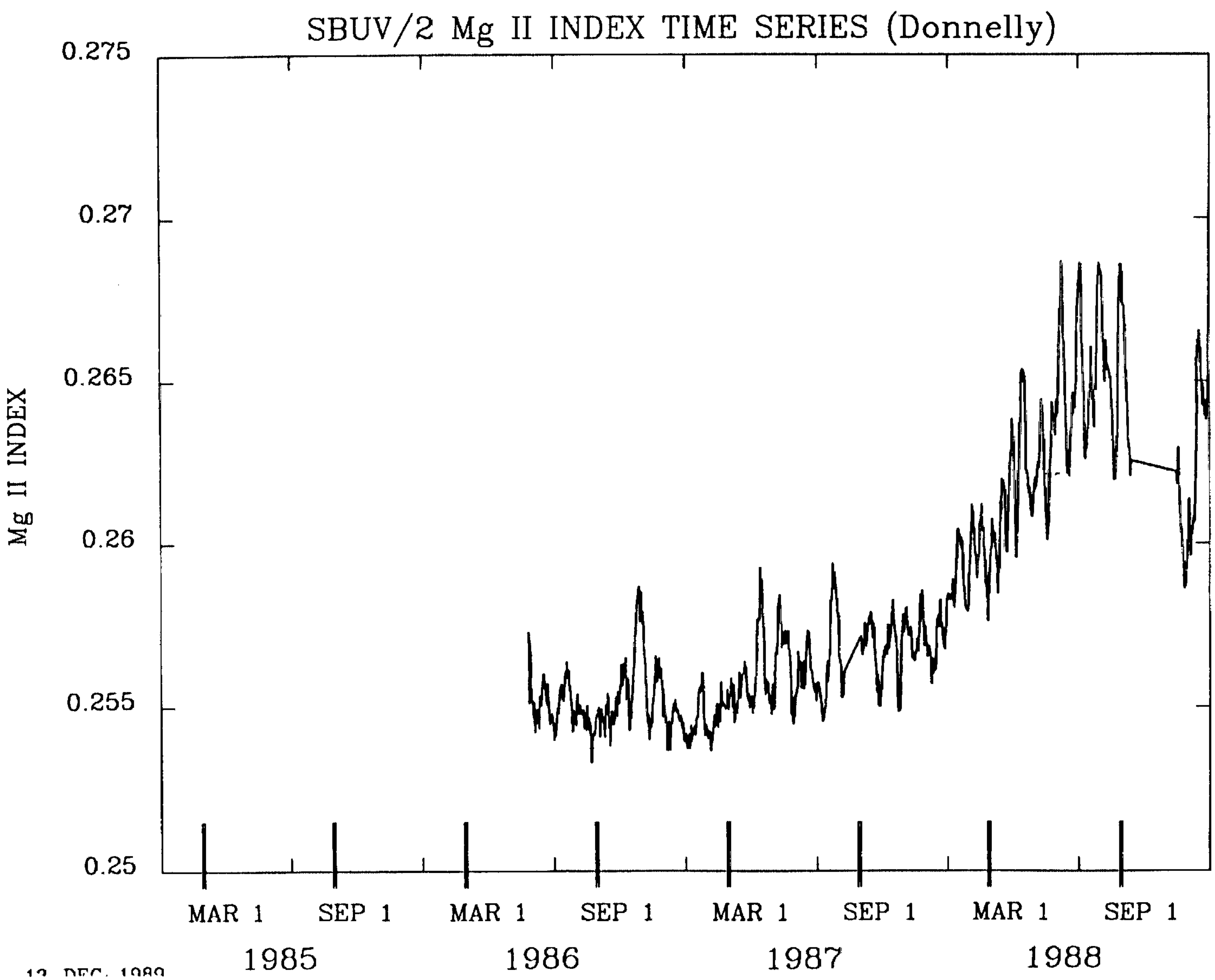
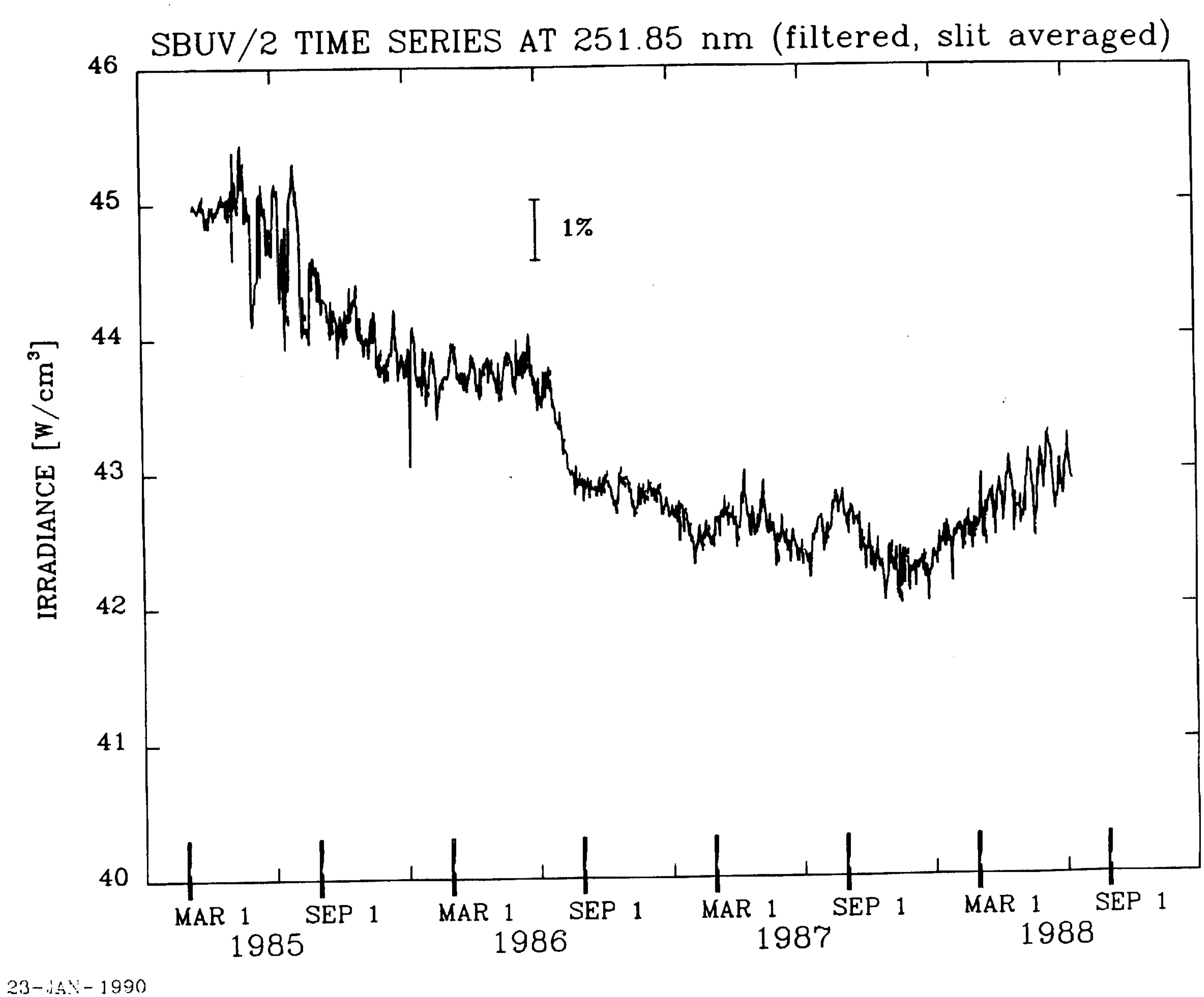
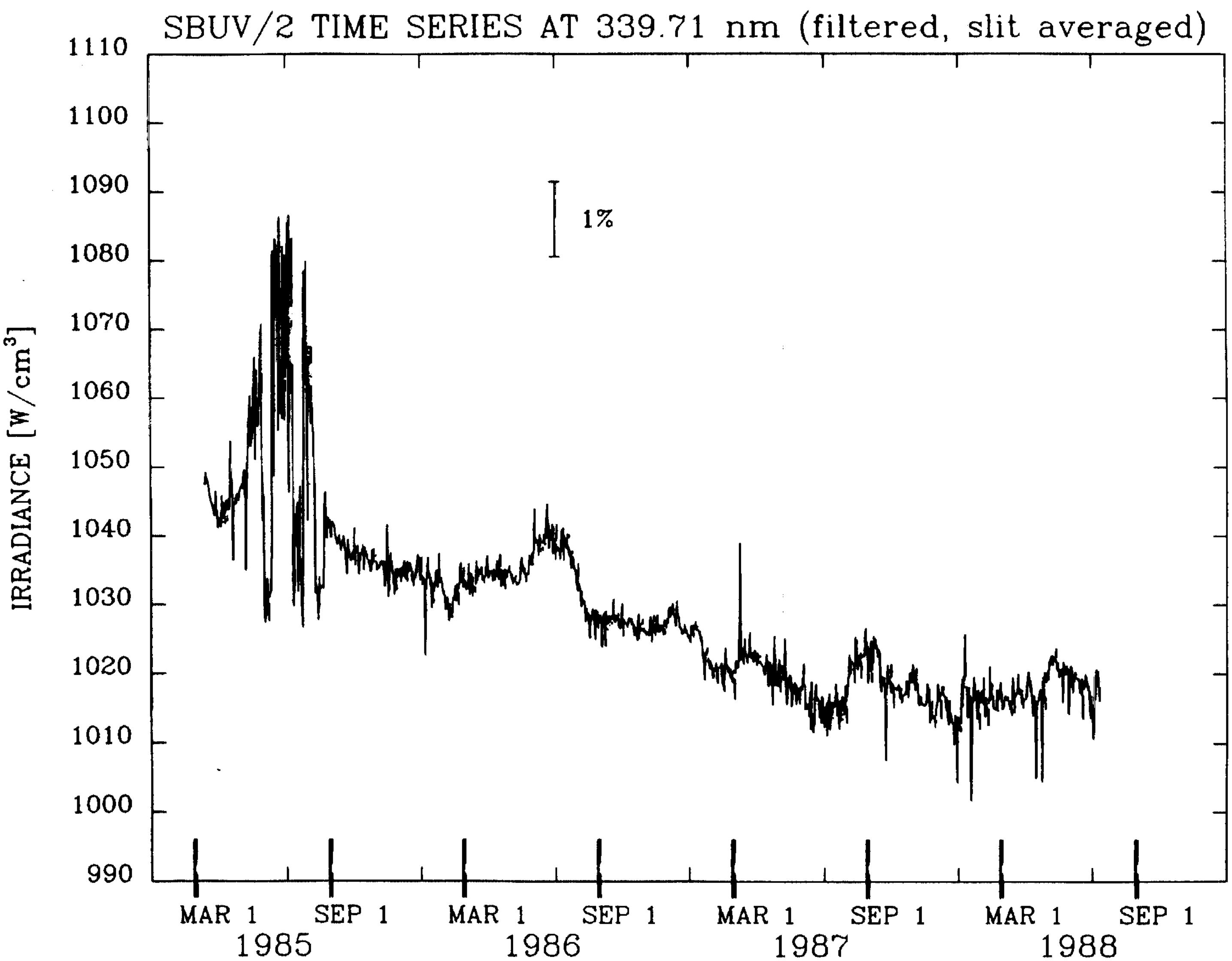

SBUV/2 Mg II INDEX TIME SERIES (Donnelly)
Mg II INDEX
0.275
0.27
0.265
0.26
0.255
0.25
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
1985
1986
1987
1988

FIGURE 12



SBUV/2 TIME SERIES AT 251.85 nm (filtered, slit averaged)
IRRADIANCE [W/cm^3]
46
45
44
43
42
41
40
1%
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
1985
1986
1987
1988
23-JAN-1990

FIGURE 13



23-JAN-1990

FIGURE 14

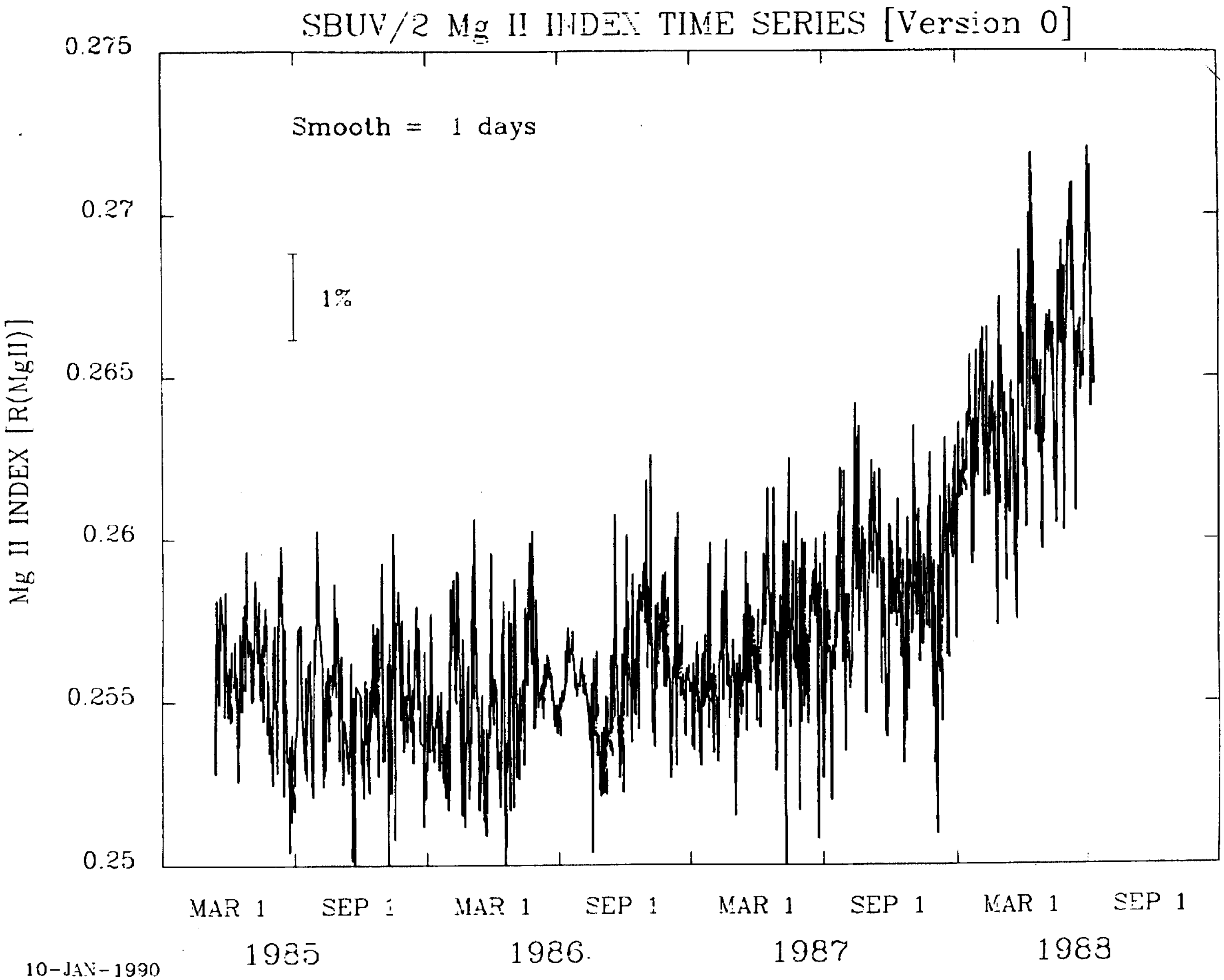
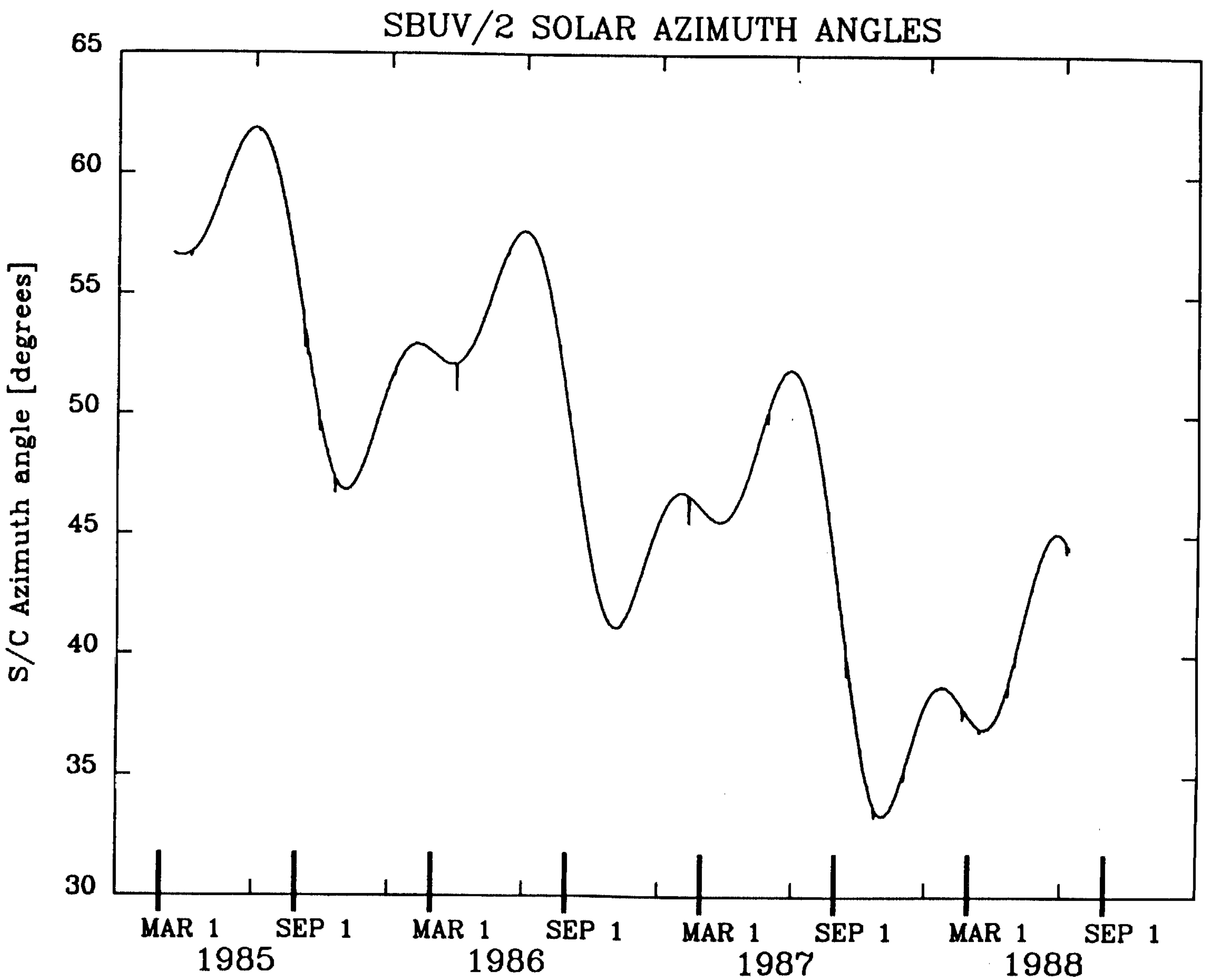

SBUV/2 Mg II INDEX TIME SERIES [Version 0]
Smooth = 1 days
1%
Mg II INDEX [R(MgII)]
0.275
0.27
0.265
0.26
0.255
0.25
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
MAR 1
SEP 1
1985
1986
1987
1988
10-JAN-1990

FIGURE 15



4-JAN-1990

Attachment 5
NOAA-9 SBUV/2 Ozone Sounding Accuracy
H. Weiss
S.T. Systems Corporation